

The embodiments of the invention in which an exclusive property right or privilege is claimed are defined as follows:

1. A vehicular vision system for displaying scenic information of an area exteriorly of a vehicle on a display system, said vision system comprising:

a focusing lens having a receiving end and a focusing end, said receiving end being opposite said focusing end;

5 a wide angle lens positioned adjacent to said receiving end of said focusing lens, said wide angle lens directing a virtual image of a wide angle field of view of a scene exteriorly of the vehicle toward said receiving end of said focusing lens, said wide angle lens including an outer negative optic and an inner negative optic, said inner negative optic being positioned between said outer negative optic and said receiving end of said focusing lens, said wide angle
10 lens including a diffractive element; and

an image capture device which is adapted to receive an image refracted through said focusing lens, said virtual image of said wide angle field of view being focused by said focusing lens on said image capture device.

2. The vehicular vision system of Claim 1 further including a display system which displays an image in response to an output of said image capture device.

3. The vehicular vision system of Claim 1, wherein said outer negative optic has an outer curved surface and an inner curved surface, said outer curved surface having a radius of curvature in a first range of approximately 40 mm to 700 mm and said inner curved surface having a radius of curvature in a second range of approximately 20 mm to 40 mm.

4. The vehicular vision system of Claim 3, wherein said first range is approximately 95.67 mm and said second range is approximately 30.00 mm.

5. The vehicular vision system of Claim 4, wherein said outer negative optic comprises one of polycarbonate, acrylic and glass.

6. The vehicular vision system of Claim 1, wherein said diffractive element is on said inner negative optic.

7. The vehicular vision system of Claim 6, wherein said diffractive element alters a phase M of energy passing therethrough according to the following equation:

$$M = A_1 \Delta^2 + A_2 \Delta^4;$$

5 where Δ is a radial aperture coordinate divided by 1 mm, A_1 is a constant within a range of approximately 15 to 55 and A_2 is a constant within a range of approximately -0.01 to -0.5.

8. The vehicular vision system of Claim 7, wherein A_1 is approximately 47.4149 and A_2 is approximately -0.1463.

9. The vehicular vision system of Claim 7, wherein said inner negative optic comprises at least one of polycarbonate and acrylic.

10. The vehicular vision system of Claim 7, wherein said diffractive element is on an outer surface of said inner negative optic toward said outer negative optic.

11. The vehicular vision system of Claim 10, wherein said outer surface of said inner negative optic has a radius of curvature in a range of approximately 20 mm to 60 mm.

12. The vehicular vision system of Claim 11, wherein said outer surface of said inner negative optic has a radius of curvature of approximately 35.3824 mm.

13. The vehicular vision system of Claim 10, wherein an inner surface of said inner negative optic is aspheric, said inner surface of said inner negative optic being opposite said outer surface of said inner negative optic.

14. The vehicular vision system of Claim 13, wherein said inner aspheric surface is defined by the following equation:

$$z = \frac{cy^2}{1 + \sqrt{1 - (1 + K)c^2 y^2}}; \quad c = \frac{1}{r_{xy}};$$

5 where x , y and z are coordinates on said inner aspheric surface along an x-axis, a y-axis and a z-axis, respectively, r_{xy} is a radius of curvature to each point on said inner aspheric surface corresponding to an x coordinate and a y coordinate, and K is a conic constant within a range of approximately -1 to -20.

15. The vehicular vision system of Claim 14, wherein K is approximately -13.3619.

16. The vehicular vision system of Claim 14, wherein a radius of curvature of a center region of said inner aspheric surface is within a range of approximately 5 mm to 30 mm.

17. The vehicular vision system of Claim 16, wherein said radius of curvature of said center region of said inner aspheric surface is approximately 23.3399 mm.

18. The vehicular vision system of Claim 16, wherein said outer surface of said inner negative optic has a radius of curvature in a third range of approximately 20 mm to 60 mm.

19. The vehicular vision system of Claim 18, wherein said outer negative optic has an outer curved surface and an inner curved surface, said outer curved surface having a radius of curvature in a first range of approximately 40 mm to 700 mm and said inner curved surface having a radius of curvature in a second range of approximately 20 mm to 40 mm.

20. The vehicular vision system of Claim 19, wherein said radius of curvature of said center region of said inner aspheric surface is approximately 23.3399 mm, said conic constant K is approximately -13.3619, said constant A_1 is approximately 47.4149, said constant A_2 is approximately -0.1463, said first range is approximately 95.67 mm, said second range is
5 approximately 30.00 mm, and said third range is approximately 35.3824 mm.

21. The vehicular vision system of Claim 19, wherein said wide angle lens provides a wide angle field of view of at least approximately 160° .

22. The vehicular vision system of Claim 1, wherein said wide angle lens provides a wide angle field of view of at least approximately 160° .

23. The vehicular vision system of Claim 1, wherein said wide angle lens comprises at least one of polycarbonate, acrylic and crown glass.

24. The vehicular vision system of Claim 23, wherein said inner negative optic comprises one of polycarbonate and acrylic and said outer negative optic comprises crown glass.

25. The vehicular vision system of Claim 1, wherein said focusing lens comprises a first optic element, a middle optic element and a third optic element, said middle optic element being positioned between said first and third optic elements, said first optic element being positioned at said receiving end of said focusing lens.
26. The vehicular vision system of Claim 25, wherein at least one of said first, middle and third optic elements includes a diffractive element thereon.
27. The vehicular vision system of Claim 26, wherein said third optic element includes said diffractive element.
28. The vehicular vision system of Claim 27, wherein said diffractive element is on a surface of said third optic element toward said middle optic element.
29. The vehicular vision system of Claim 1 further including an optical filter positioned between said focusing lens and said wide angle lens.
30. The vehicular vision system of Claim 29, wherein said optical filter attenuates near infrared wavelengths of energy.
31. The vehicular vision system of Claim 25, wherein each of said first, middle and third optic elements comprise plastic.
32. The vehicular vision system of Claim 1, wherein an outer surface of said outer negative optic is coated with a protective coating.
33. The vehicular vision system of Claim 1, wherein an outer surface of one of said inner and outer negative optics includes a heating element.
34. The vehicular vision system of Claim 33, wherein said heating element is one of an indium tin oxide conductor, a doped tin oxide and a conductive mesh.
35. The vehicular vision system of Claim 1, wherein an outer surface of said outer negative optic is coated with at least one of an anti-soiling material and anti-wetting material.

36. The vehicular vision system of Claim 1, wherein at least a portion of said wide angle lens is at least occasionally positioned exteriorly of the vehicle.
37. The vehicular vision system of Claim 36, wherein said wide angle lens is movable between a storage position where said wide angle lens is positioned interiorly of the vehicle and an operable position where said portion of said wide angle lens is positioned exteriorly of the vehicle.
38. The vehicular vision system of Claim 1, wherein said image capture device is a pixelated-imaging array.
39. The vehicular vision system of Claim 38, wherein said image capture device is a CMOS imaging array.
40. The vehicular vision system of Claim 2, wherein at least one of said image capture device and said display system are occasionally activated in response to one of an input from one of a driver and the vehicle.
41. The vehicular vision system of Claim 40, wherein said input is provided by one of an audible message from the driver and an engagement of a reverse gear of the vehicle.
42. The vehicular vision system of Claim 1, wherein said wide angle field of view includes a vehicle body reference therein.
43. The vehicular vision system of Claim 42, wherein said wide angle lens is positioned on a rearward portion of the vehicle, said image capture device capturing an image of an area rearwardly of the vehicle, said vehicle body reference being a rear bumper of the vehicle.
44. The vehicular vision system of Claim 43, wherein said wide angle lens is positioned on a side portion of the vehicle, said image capture device capturing an image of an area sidewardly of the vehicle, said vehicle body reference being at least one side of the vehicle.
45. The vehicular vision system of Claim 1, wherein said wide angle lens, said focusing lens and said image capture device are positioned at one of a rear spoiler of the vehicle, a rim

molding of a window of the vehicle, a badge of the vehicle and a license plate holder of the vehicle.

46. The vehicular vision system of Claim 1 further including an illumination source for providing illumination toward an exterior area being captured by said image capture device.

47. The vehicular vision system of Claim 46, wherein said illumination source is one of a light emitting diode and an electro-illuminous material.

48. The vehicular vision system of Claim 46, wherein said illumination source provides one of visible radiation, near-infrared radiation and non-visible infrared radiation.

49. The vehicular vision system of Claim 48, wherein said illumination source provides radiation in a range between approximately 0.7 microns to 2.5 microns of an electro-magnetic radiation spectrum.

50. The vehicular vision system of Claim 46, wherein said illumination source is only occasionally activated.

51. The vehicular vision system of Claim 50, wherein said illumination source is activated by one of the vehicle engaging a reverse gear, a photo-sensor control when a photo-sensor detects ambient light below a threshold value and a voice activation system.

52. The vehicular vision system of Claim 1 further including a ranging device, said ranging device determining a distance between the vehicle and an object within the image received by said image capture device, said ranging device communicating the distance to a driver of the vehicle.

53. The vehicular vision system of Claim 52 further including a display which displays an image in response to an output of said image capture device, said display including a range indication.

54. The vehicular vision system of Claim 52, wherein said ranging device communicates a signal to the driver which varies with the proximity of the object to the vehicle.

55. The vehicular vision system of Claim 2, wherein said display system displays the image at a focal length that is forward of a vehicle passenger compartment.

56. The vehicular vision system of Claim 1, wherein said image capture device is movable by a remote control such that said image capture device is capable of at least one of zooming or panning within an area exteriorly of the vehicle.

57. The vehicular vision system of Claim 1 further including an electronic image control which provides an ability to pan or zoom within a field of view captured by said image capture device.

58. The vehicular vision system of Claim 1, wherein said vision system is connected to an image recording system to occasionally record events occurring exteriorly of the vehicle.

59. The vehicular vision system of Claim 1, wherein said vision system measures a contrast ratio of the image occurring exteriorly of the vehicle to determine when visibility conditions change.

60. The vehicular vision system of Claim 59, wherein said vision system communicates information to a driver of the vehicle which varies according to the contrast ratio.

61. A vehicular vision system for providing scenic information of an area exteriorly of a vehicle, said vision system comprising:

a focusing lens having a receiving end and a focusing end, said receiving end being opposite said focusing end, said focusing lens comprising an outer focusing optic at said receiving end, a middle focusing optic and an inner focusing optic at said focusing end, said middle optic being positioned between said outer and inner focusing optics, each of said outer focusing optic, said middle focusing optic and said inner focusing optic comprising one of polycarbonate and acrylic;

a wide angle lens comprising an outer wide angle optic and an inner wide angle optic, said wide angle lens being positioned near said receiving end of said focusing lens, said wide angle lens refracting a virtual image of the area exteriorly of the vehicle toward said receiving end of said focusing lens, each of said outer wide angle optic and said inner wide angle optic comprising at least one of polycarbonate and acrylic;

an image capture device which is adapted to receive a focused image refracted through
15 said focusing lens, said virtual image of said wide angle field of view being focused by said
focusing lens on said image capture device; and

a display system which displays an image in response to an output of said image capture
device.

62. The vehicular vision system of Claim 61 further including an optical filter positioned
between said focusing lens and said wide angle lens.

63. The vehicular vision system of Claim 62, wherein said optical filter attenuates near
infrared wavelengths of energy.

64. The vehicular vision system of Claim 61, wherein said inner focusing optic includes a
diffractive element.

65. The vehicular vision system of Claim 64, wherein said diffractive element is on an outer
surface of said inner focusing optic toward said middle focusing optic.

66. The vehicular vision system of Claim 65, wherein said outer and middle focusing optics
include elliptical aspheric surfaces on an inner surface of each which is toward said inner
focusing optic, said inner focusing optic including an aspheric surface on an inner surface
opposite of said diffractive element.

67. The vehicular vision system of Claim 66, wherein said inner surface of said outer
focusing optic has a radius of curvature of approximately 1.60 mm and is defined by the
equation:

$$z = \frac{cy^2}{1 + \sqrt{1 - (1 + K)c^2y^2}}; \quad c = \frac{1}{r_{xy}};$$

5 where x , y and z are coordinates on said inner surface of said outer focusing optic along an x -
axis, a y -axis and a z -axis, respectively, r_{xy} is a radius of curvature to each point on said inner
surface of said outer focusing optic corresponding to an x coordinate and a y coordinate, and K is
a conic constant of approximately -0.2723, an outer surface of said outer focusing optic having a
radius of curvature of approximately 3.073 mm, said outer surface of said outer focusing optic
10 being opposite said inner surface of said outer focusing optic.

68. The vehicular vision system of Claim 67, wherein said inner surface of said middle focusing optic has a radius of curvature of approximately 3.5109 mm and is defined by the equation:

$$z = \frac{cy^2}{1 + \sqrt{1 - (1 + K)c^2 y^2}}; \quad c = \frac{1}{r_{xy}};$$

5 where x , y and z are coordinates on said inner surface of said middle focusing optic along an x -axis, a y -axis and a z -axis, respectively, r_{xy} is a radius of curvature to each point on said inner surface of said middle focusing optic corresponding to an x coordinate and a y coordinate, and K is a conic constant of approximately -0.527 , an outer surface of said middle focusing optic having a radius of curvature of approximately 166.3208 mm, said outer surface of said middle
10 focusing optic being opposite said inner surface of said middle focusing optic.

69. The vehicular vision system of Claim 68, wherein said inner focusing optic has an outer diffractive element toward said middle focusing optic, said outer diffractive element having a radius of curvature of approximately 9.3651 mm and altering a phase M of energy passing therethrough according to the following equation:

$$5 \quad M = A_1 \Delta^2 + A_2 \Delta^4;$$

where Δ is a radial aperture coordinate divided by 1 mm, A_1 is a constant of approximately -71.9397 and A_2 is a constant of approximately -0.3594 , said inner focusing optic having an inner aspheric surface opposite to said outer diffractive element, said inner aspheric surface having a radius of curvature of approximately 809.8961 mm and being defined by the equation:

$$10 \quad z = \frac{cy^2}{1 + \sqrt{1 - (1 + K)c^2 y^2}} + \alpha y^4; \quad c = \frac{1}{r_{xy}};$$

where x , y and z are coordinates on said inner aspheric surface along an x -axis, a y -axis and a z -axis, respectively, r_{xy} is the radius of curvature to each point on the surface corresponding to an x coordinate and a y coordinate, α is a constant equal to approximately 0.0006 and K is a conic constant equal to approximately zero.

70. The vehicular vision system of Claim 69, wherein said outer wide angle optic has an outer surface and inner surface, said outer surface of said outer wide angle optic having a radius of curvature in a first range of approximately 40 mm to 700 mm and said inner surface of said outer wide angle optic having a radius of curvature in a second range of approximately 20 mm to

5 40 mm, said inner surface of said outer wide angle optic being on a side toward said inner wide angle optic.

71. The vehicular vision system of Claim 70, wherein said first range is approximately 95.67 mm and said second range is approximately 30.00 mm.

72. The vehicular vision system of Claim 70, wherein said inner wide angle optic includes a wide angle diffractive element.

73. The vehicular vision system of Claim 72, wherein said wide angle diffractive element alters a phase M of energy passing therethrough according to the following equation:

$$M = A_1 \Delta^2 + A_2 \Delta^4;$$

5 where Δ is a radial aperture coordinate divided by 1 mm, A_1 is a constant within a range of approximately 15 to 55 and A_2 is a constant within a range of approximately -0.01 to -0.5.

74. The vehicular vision system of Claim 73, wherein A_1 is approximately 47.4149 and A_2 is approximately -0.1463.

75. The vehicular vision system of claim 73, wherein said wide angle diffractive element is on an outer surface of said inner wide angle optic toward said outer wide angle optic.

76. The vehicular vision system of Claim 75, wherein said outer surface of said inner wide angle optic has a radius of curvature in a range of approximately 20 mm to 60 mm.

77. The vehicular vision system of Claim 76, wherein said outer surface of said inner wide angle optic has a radius of curvature of approximately 35.3824 mm.

78. The vehicular vision system of Claim 76, wherein an inner surface of said inner wide angle optic is aspheric, said inner surface of said inner wide angle optic being toward said receiving end of said focusing lens.

79. The vehicular vision system of Claim 78, wherein said inner aspheric surface is defined by the following equation:

$$z = \frac{cy^2}{1 + \sqrt{1 - (1 + K)c^2y^2}}; \quad c = \frac{1}{r_{xy}};$$

where x , y and z are coordinates on said inner aspheric surface along an x -axis, a y -axis and a z -axis, respectively, r_{xy} is a radius of curvature to each point on said inner aspheric surface corresponding to an x coordinate and a y coordinate, and K is a conic constant within a range of approximately -1 to -20.

80. The vehicular vision system of Claim 79, wherein K is approximately -13.3619.

81. The vehicular vision system of Claim 79, wherein said radius of curvature of said inner aspheric surface is within a range of approximately 5 mm to 30 mm.

82. The vehicular vision system of Claim 81, wherein said radius of curvature of said inner aspheric surface is approximately 23.3399 mm.

83. The vehicular vision system of Claim 61, wherein said wide angle lens provides a wide angle field of view of at least approximately 160°.

84. The vehicular vision system of Claim 61, wherein said outer wide angle optic comprises a crown glass material and said inner wide angle optic comprises one of a polycarbonate and acrylic materials.

85. The vehicular vision system of claim 61, wherein said image capture device is a pixelated imaging array.

86. The vehicular vision system of claim 85, wherein said image capture device is a CMOS imaging array.

87. A vehicular vision system comprising:

a wide angle lens group positionable on a portion of a vehicle for refracting a virtual image of an exterior view from the vehicle, thereby creating a wide angle refracted image, said wide angle lens group including an outer negative optic and an inner negative optic, said wide angle lens group comprising at least one of a polycarbonate and acrylic material;

a focusing lens group which receives said refracted image and focuses the refracted image onto an image plane;

an image capture device positioned on said image plane to receive the focused image from said focusing lens group, said wide angle lens group and said focusing lens group defining
10 an optic path between an outer end of said wide angle lens group and said image capture device;

an image distortion correction process whereby an image captured by said vision system is processed to correct distortion therein; and

a display which displays a substantially non-distorted image of the scenic information, the non-distorted image being communicated from said image distortion process.

88. The vehicular vision system of Claim 87, wherein said focusing lens group includes a refractive and diffractive lens element positioned along said optic path.

89. The vehicular vision system of Claim 87, wherein said focusing lens group is constructed of one of polycarbonate and acrylic.

90. The vehicular vision system of Claim 87, wherein said image distortion correction process is at least partially provided by a plurality of refractive optics.

91. The vehicular vision system of Claim 90, wherein said focusing lens group includes at least one diffractive element positioned along said optic path, said diffractive element correcting color focusing of the refracted image.

92. The vehicular vision system of Claim 90, wherein said wide angle lens group includes at least one wide angle diffractive element positioned along said optic path, said wide angle diffractive element correcting color focusing of the refracted virtual image.

93. The vehicular vision system of Claim 92, wherein said wide angle diffractive element is on an outer surface of said inner negative optic, said wide angle diffractive element being defined by the equation:

$$M = A_1 \rho^2 + A_2 \rho^4$$

5 where Δ is a radial aperture coordinate divided by 1 mm, A_1 is a constant within a range of approximately 15 to 55 and A_2 is a constant within a range of approximately -0.01 to -0.5.

94. The vehicular vision system of Claim 95, wherein A_1 is approximately 47.4149 and A_2 is approximately -0.1463.

95. The vehicular vision system of Claim 93, wherein said outer surface of said inner negative optic has a radius of curvature in a range of approximately 20 mm to 60 mm.

96. The vehicular vision system of Claim 95, wherein said outer surface of said inner negative optic has a radius of curvature of approximately 35.3824 mm.

97. The vehicular vision system of Claim 95, wherein said inner negative optic has an inner aspheric surface opposite said outer wide angle diffractive element, said inner aspheric surface being defined by the following equation:

$$z = \frac{cy^2}{1 + \sqrt{1 - (1 + K)c^2y^2}}; \quad c = \frac{1}{r_{xy}};$$

5 where x , y and z are coordinates on said inner aspheric surface along an x -axis, a y -axis and a z -axis, respectively, r_{xy} is a radius of curvature to each point on said inner aspheric surface corresponding to an x coordinate and a y coordinate, and K is a conic constant within a range of approximately -1 to -20.

98. The vehicular vision system of Claim 97, wherein K is approximately -13.3619.

99. The vehicular vision system of Claim 97, wherein said outer negative optic has an outer surface and an inner surface, said outer surface of said outer negative optic having a radius of curvature of approximately 40 mm to 700 mm, said inner surface of said outer negative optic having a radius of curvature of approximately 20 mm to 40 mm, said inner surface of said outer negative optic being on a side toward said inner negative optic.

100. The vehicular vision system of Claim 91, wherein said wide angle lens group includes at least one wide angle diffractive element positioned along said optic path, said wide angle diffractive element correcting color focusing on the refracted image.

101. The vehicular vision system of Claim 87, wherein said image distortion correction process is provided by said image capture device.

102. The vehicular vision system of Claim 101, wherein said image capture device is a CMOS imaging array including a non-uniform array of pixels, said non-uniform array having a coarse distribution of said pixels in portions corresponding to the refracted image where there is minimal distortion and a fine distribution of said pixels in portions corresponding to the refracted image where there is greater distortion, the refracted image being received by said non-uniform pixels and communicated to a uniform array on said display, said display thereby receiving and displaying a uniform, substantially non-distorted image to the operator of the vehicle.

103. The vehicular vision system of Claim 87, wherein said image distortion correction process is provided by electronic processing of the image received by said vision system.

104. The vehicular vision system of Claim 87, wherein said outer negative optic comprises crown glass and said inner negative optic comprises one of polycarbonate and acrylic.